

# Spatial and Temporal Distributions of Retrieved O<sub>3</sub>, CO, H<sub>2</sub>O and Temperature from the Airborne Emission Spectrometer (AES)

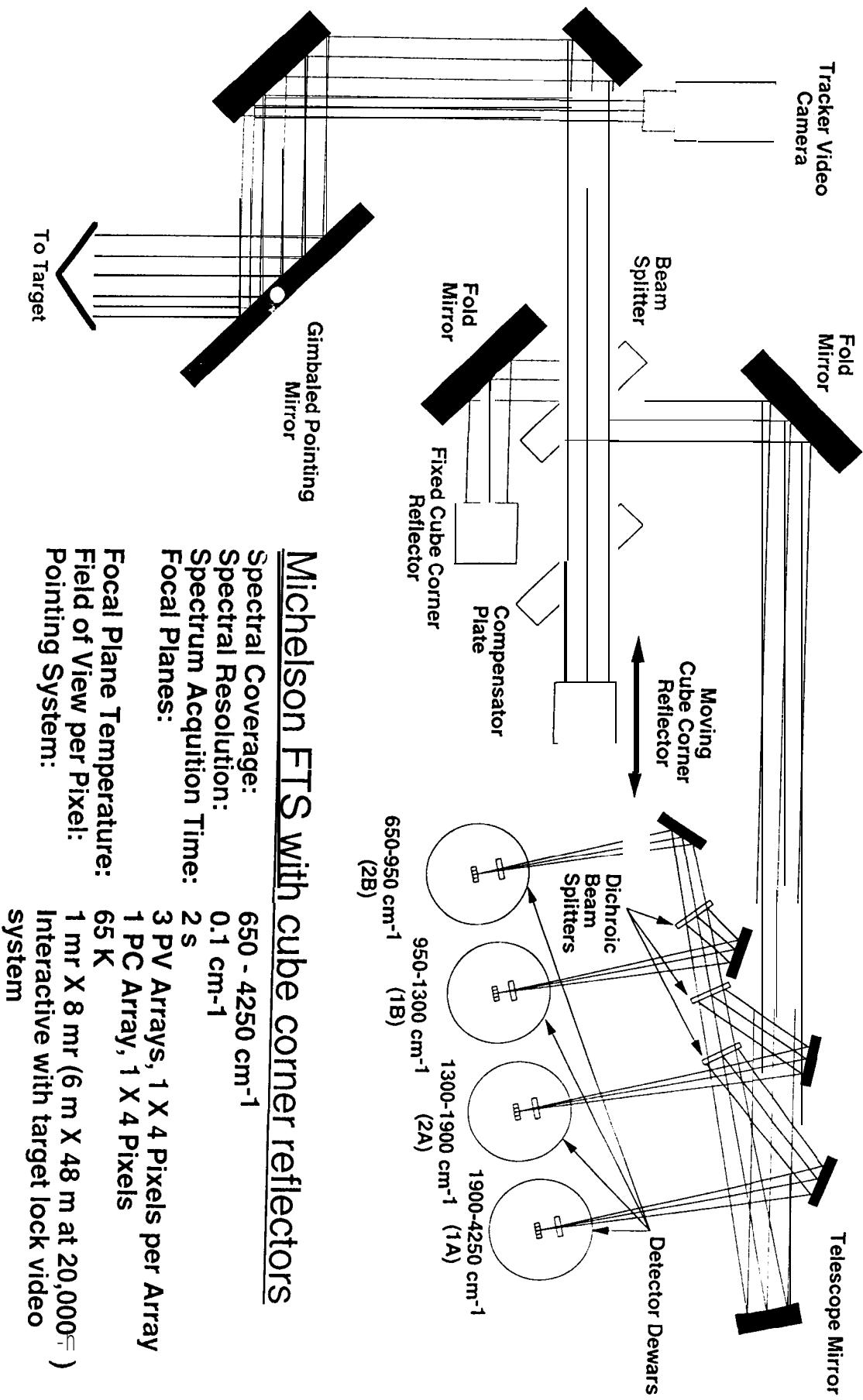
N. Worden, R. Beer, S. Nandi, D. Rider

- The Southern Oxidants Study (SOS)
- The AES instrument and the SOS 995 data set
- Retrieval of atmospheric parameters from spectral data
- Results: maps and time series for temperature, O<sub>3</sub>, H<sub>2</sub>O and CO
- Comparisons with other measurements

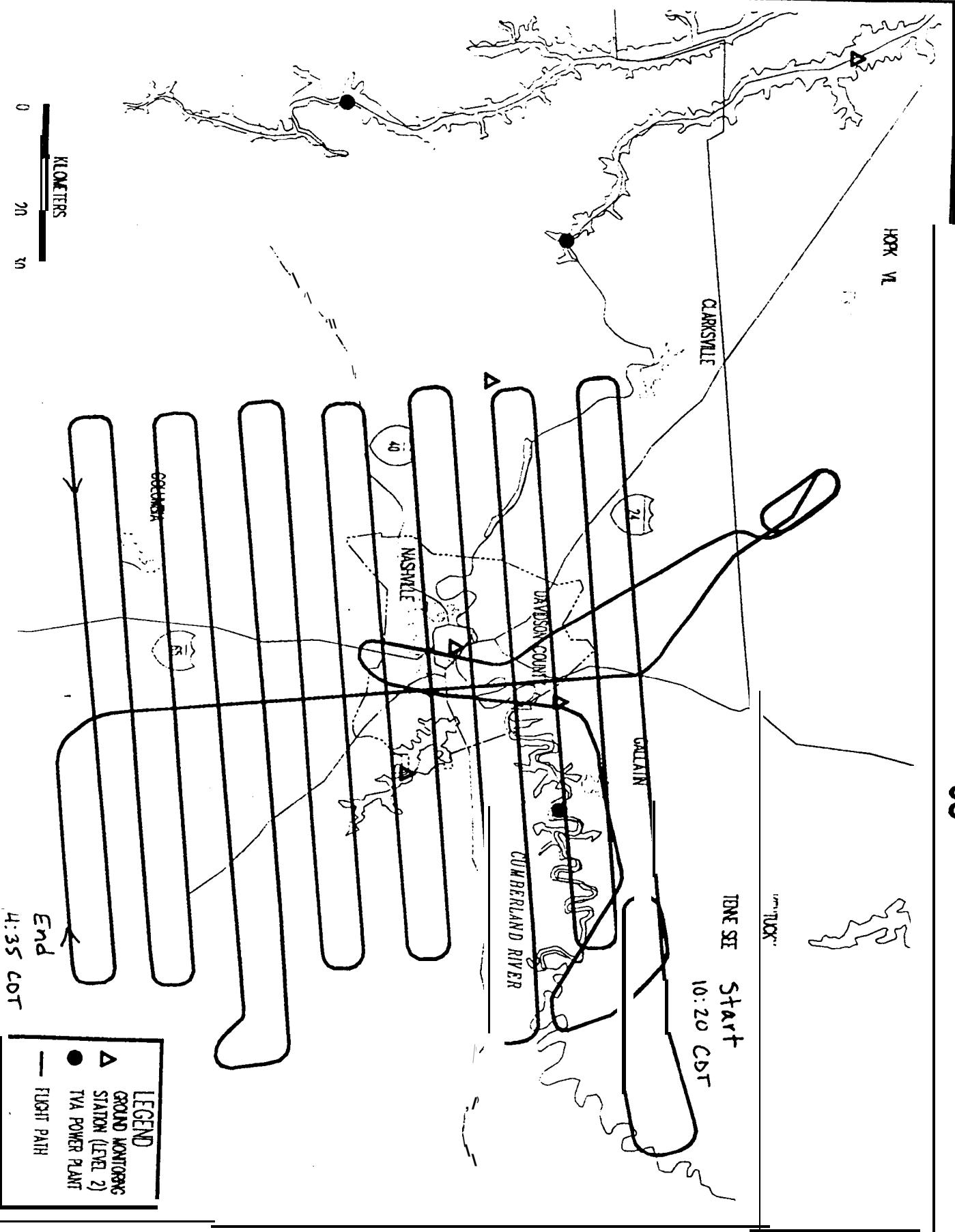
## The Southern Oxidants Study (SOS)

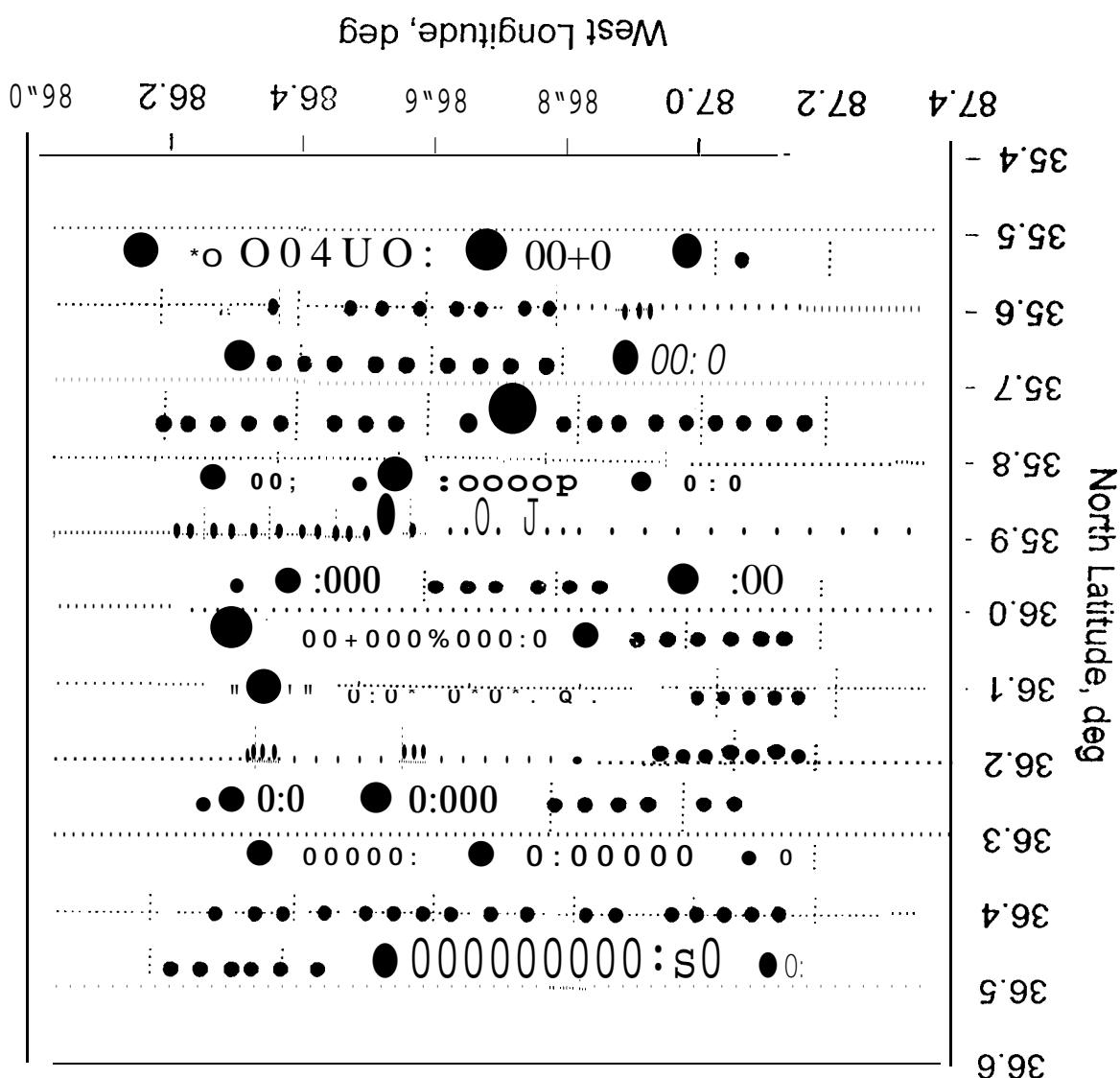
- Ongoing study to understand ground level ozone production and transport in the southeastern U.S.
- Started in 1988 in response to Clean Air Act to address problem of episodes in the Nashville, TN when ozone levels exceeded the federal standard. Behavior of ozone episodes is different for this area; not as intense but of longer duration than other parts of the country.
- The principal sponsors include: EPA, Electric Power Research Inst., NOAA, DOE, TVA, and this year, NASA. Participating universities: Georgia Tech, N. Carolina State Univ., Univ. of Alabama, Univ. of Miami, Univ. of Michigan and Univ. of Tennessee.
- 1995 summer measurement campaign included:
  - > 90 level 1 stations (O<sub>3</sub> monitors) throughout the region
  - 5 level 2 stations (enhanced chemistry monitoring + me data)
  - daily ozonesonde (T, O<sub>3</sub>, R.H. profiles)
  - 5 aircraft:
- NOAA P3, DOE/BNL G      array of *in situ* measurements  
NOAA Twin Otter            O<sub>3</sub> lidar  
TVA helicopter            power plant plumes  
NASA C-130                remote sensing w/ broad regional coverage (AES)

# Airborne Emission Spectrometer Optical Layout



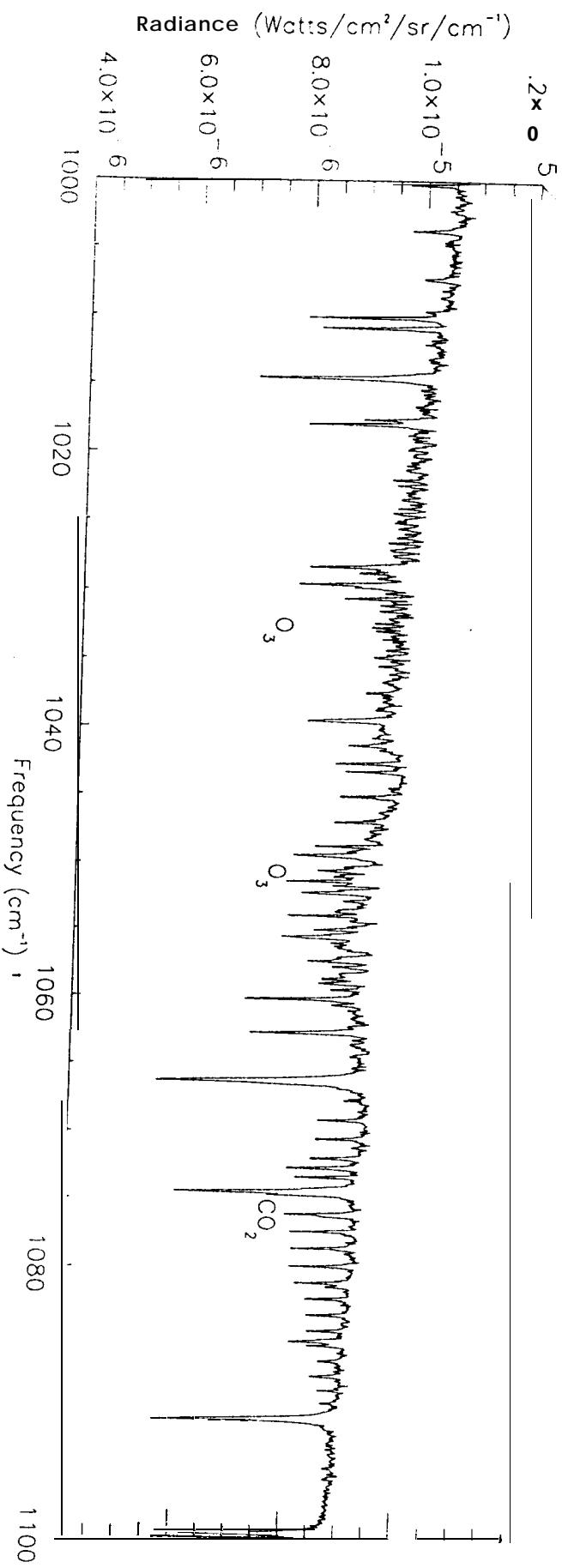
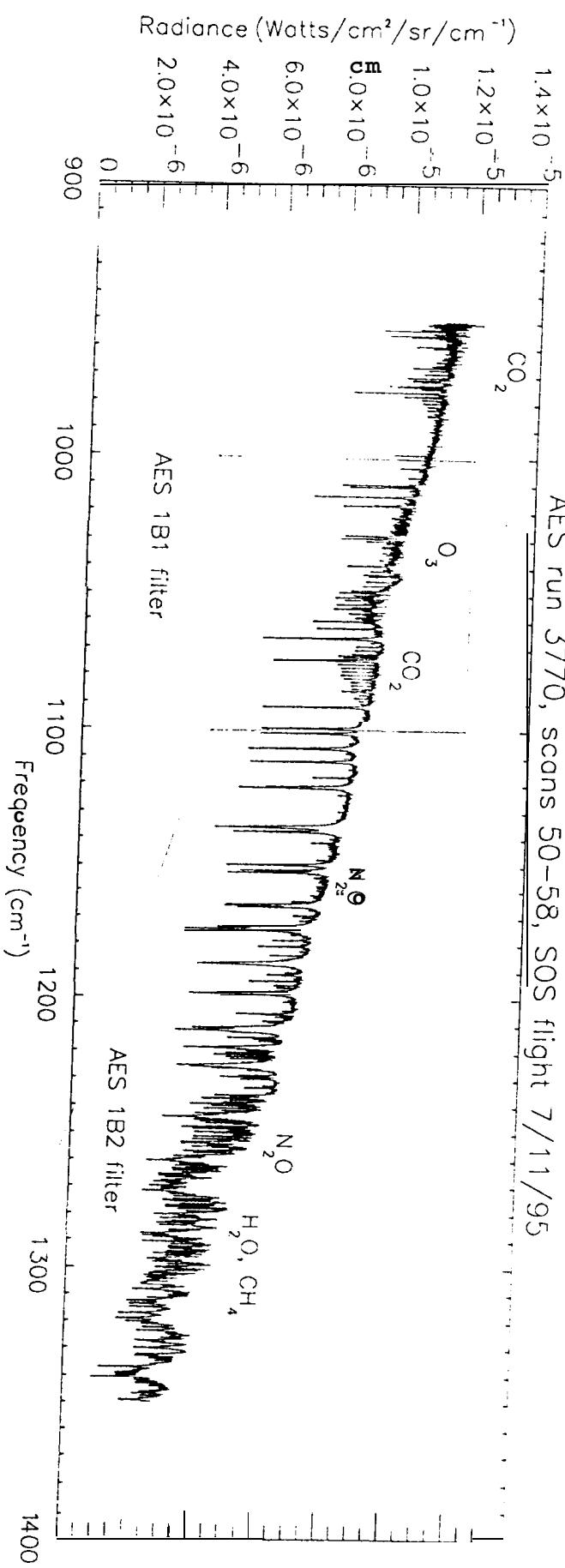
NASA-JPL C-130 7/11/95





Nashville-Middle Tennessee  
Sample Locations, 07/11/95

AES run 3770, scans 50-58, SOS flight 7/11/95



## AES Data from the SOS campaign

### Processing Challenges

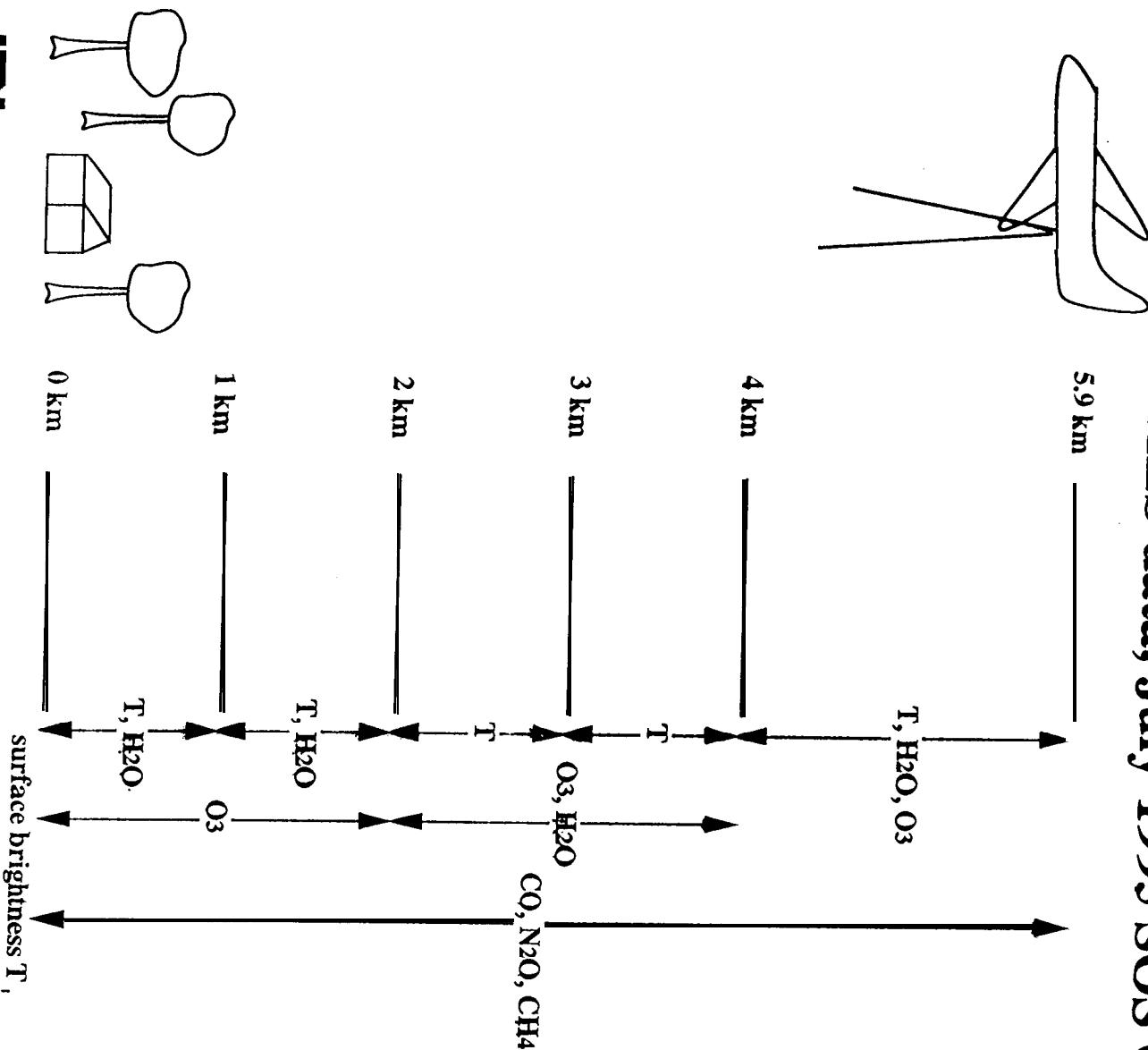
**For each flight:**  
 6 AES flights: 7/7, 7/8, 7/11, 7/12, 7/13 and 7/15 (1995)

- Approx. 50,000 target and 20,000 calibration interferograms (19K points each) must be converted to spectra.

- Calibrated target spectra are averaged into observation sets corresponding to ground targets acquired with "step and stare" tracking -- typically 8 scans and 4 pixels are averaged together (approx. 24m x 48m footprint) resulting in ~250 observation sets per day.
- Atmospheric temperatures are retrieved using "small" spectral range  $750\text{-}775 \text{ cm}^{-1}$  (420 spectral points).
- Using retrieved temperatures, atmospheric abundance parameters are retrieved for the spectral ranges: 750-900, 950-1350 and 1950-2200  $\text{cm}^{-1}$  (14364 spectral points).
- Retrievals converge in 2 to 3 iterations - about 5 min/iteration running SEASCAPE on a SUN Ultra-2.

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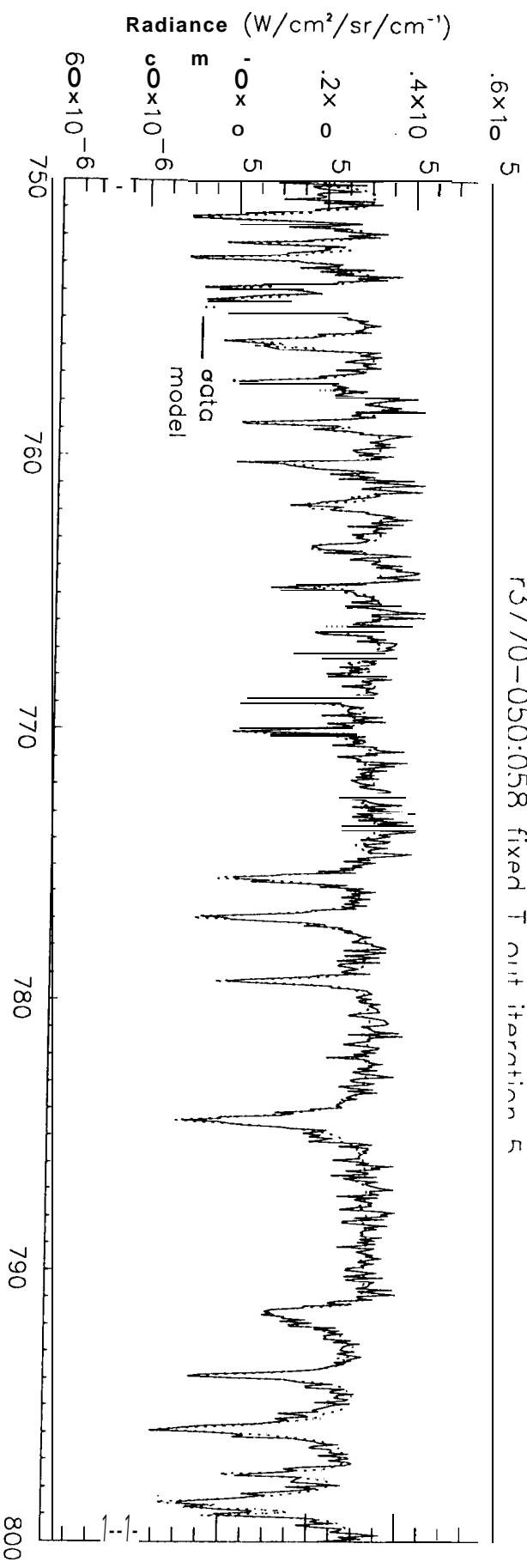
# Model Layers and Retrieved Parameters AES data, July 1995 SOS Campaign



Initial guesses for  $T, H_2O$  and  $O_3$  values are from daily ozonesondes.

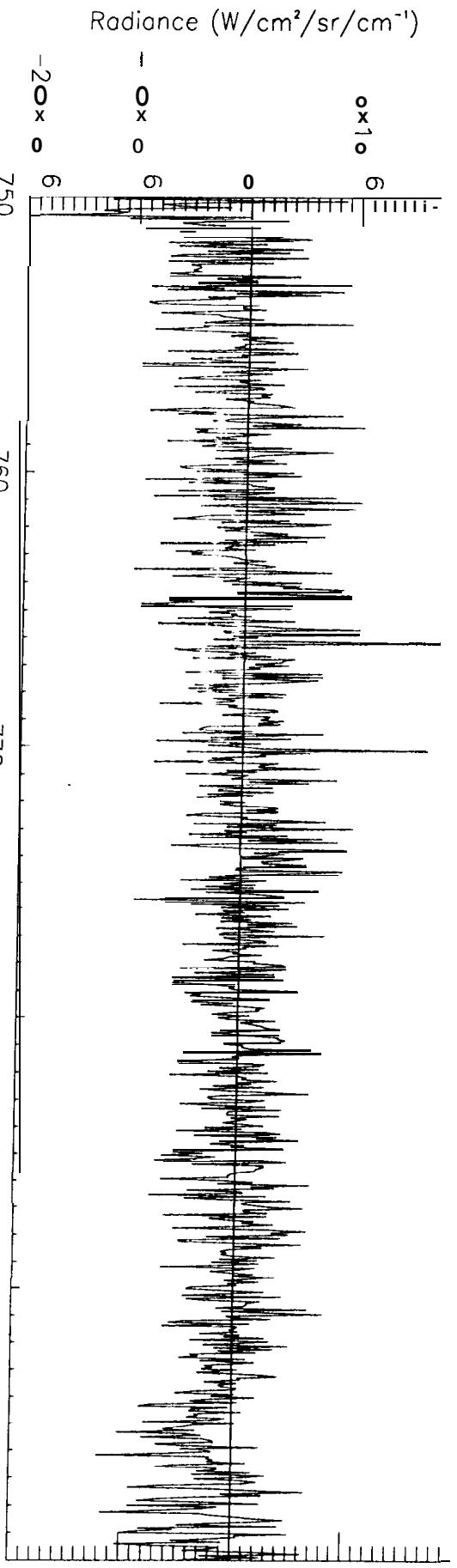
Correlation distance of 8 km is used to generate a priori correlation for temperature parameters.

r3770-050:058 fixed T init iteration 5

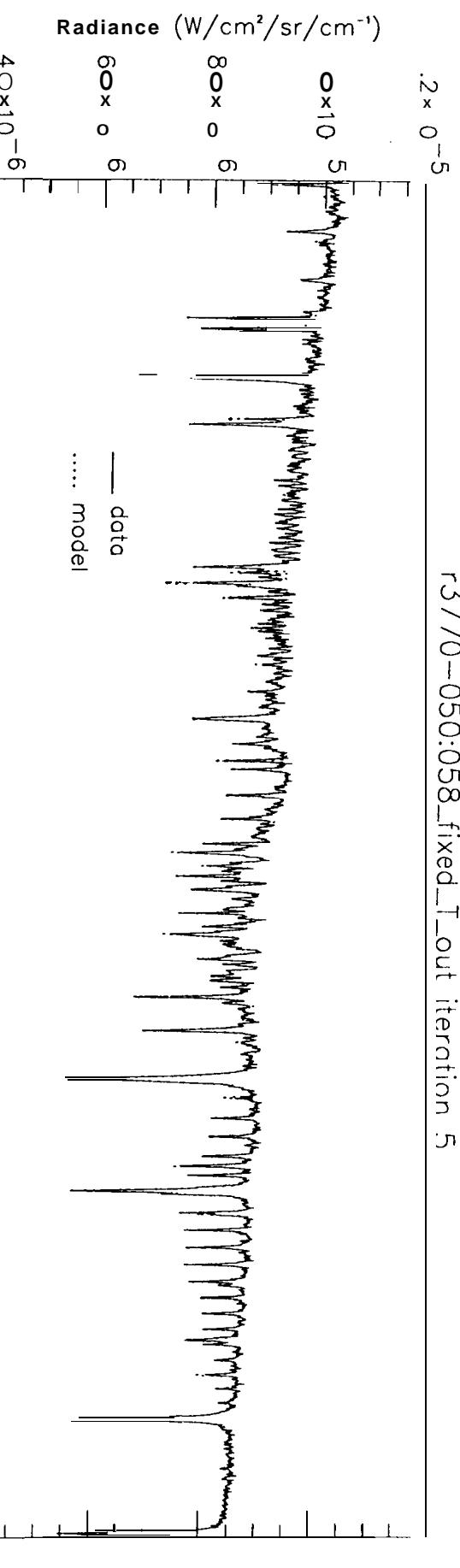


20x 0 6  
0x10 6  
-20x 0 6

data-model



r3770-050:058\_fixed\_T\_out iteration 5



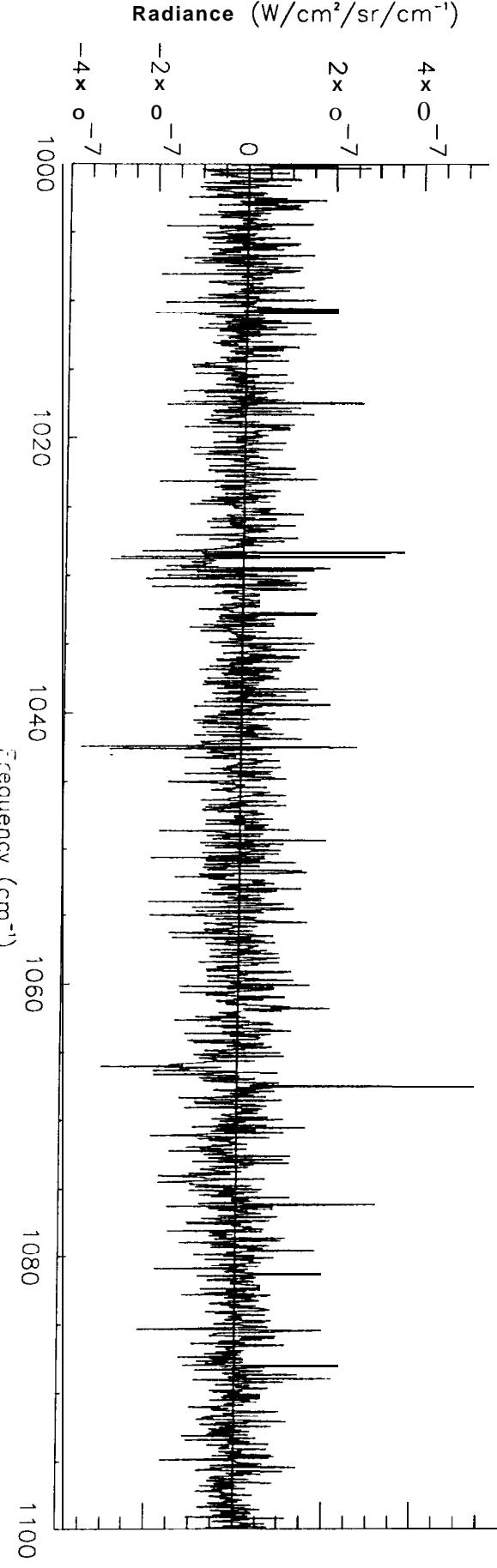
6x 0<sup>-7</sup>

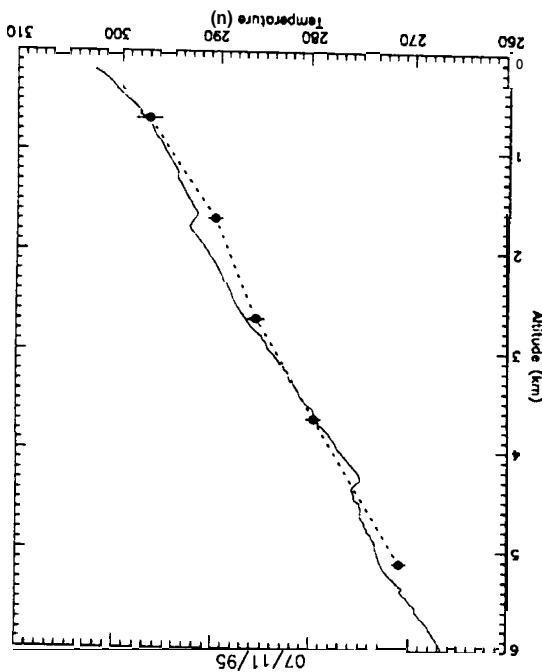
4x 0<sup>-7</sup>

2x 0<sup>-7</sup>

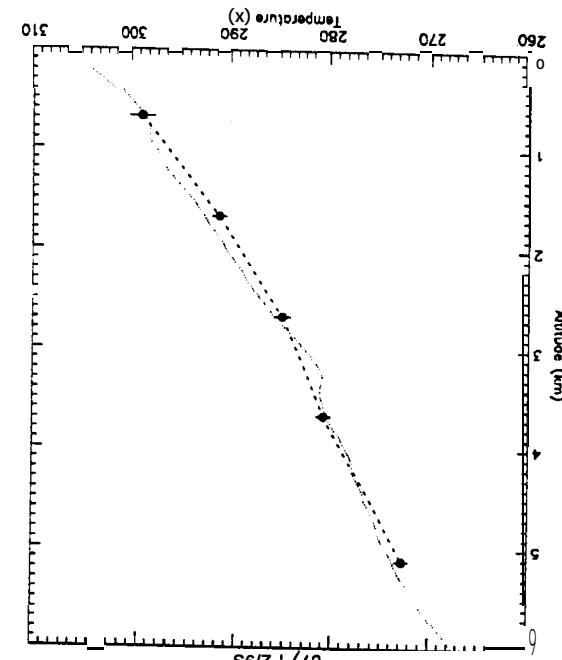
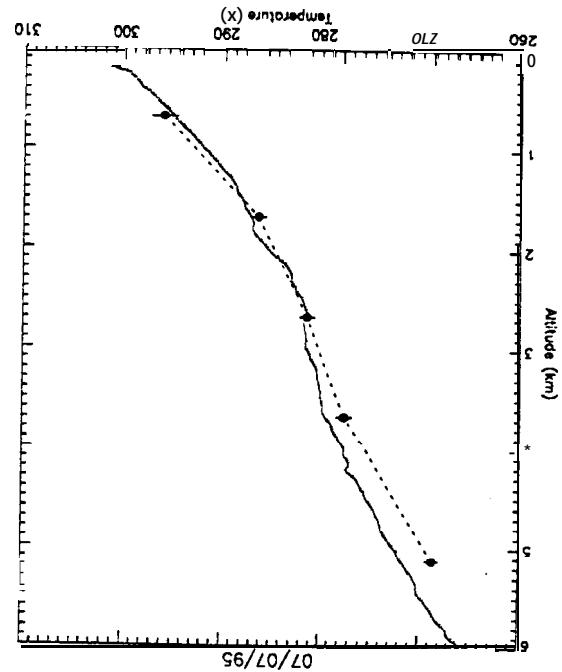
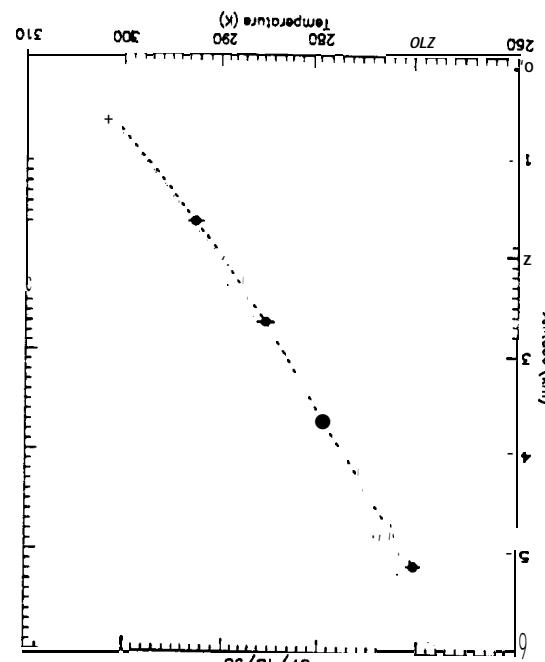
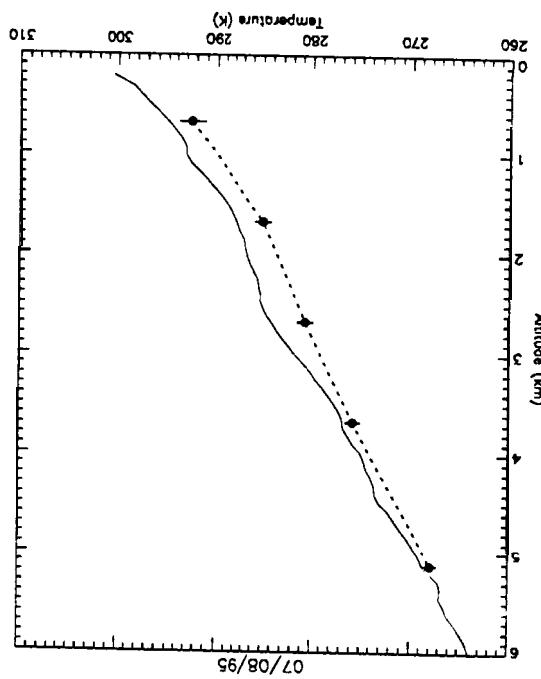
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data-model

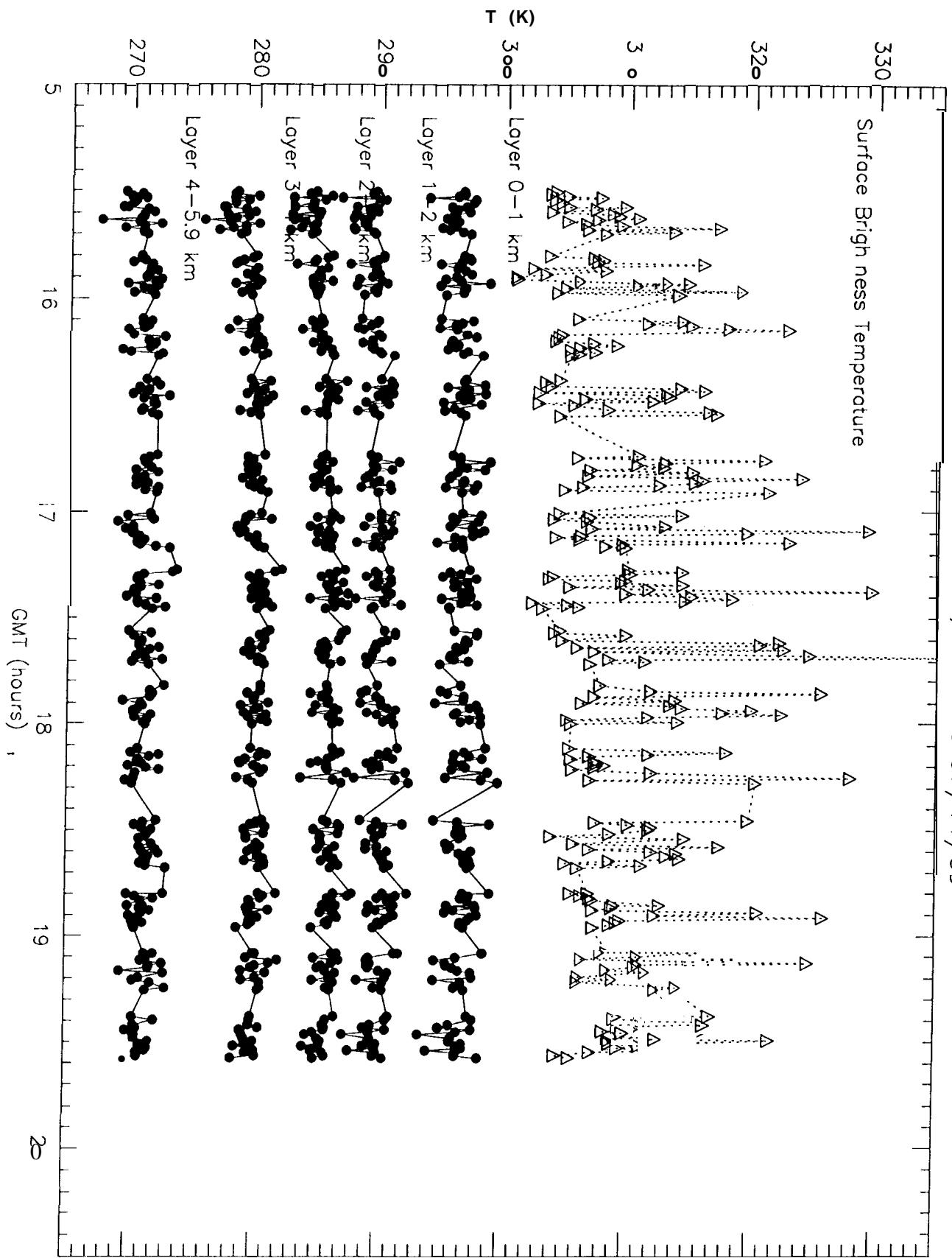




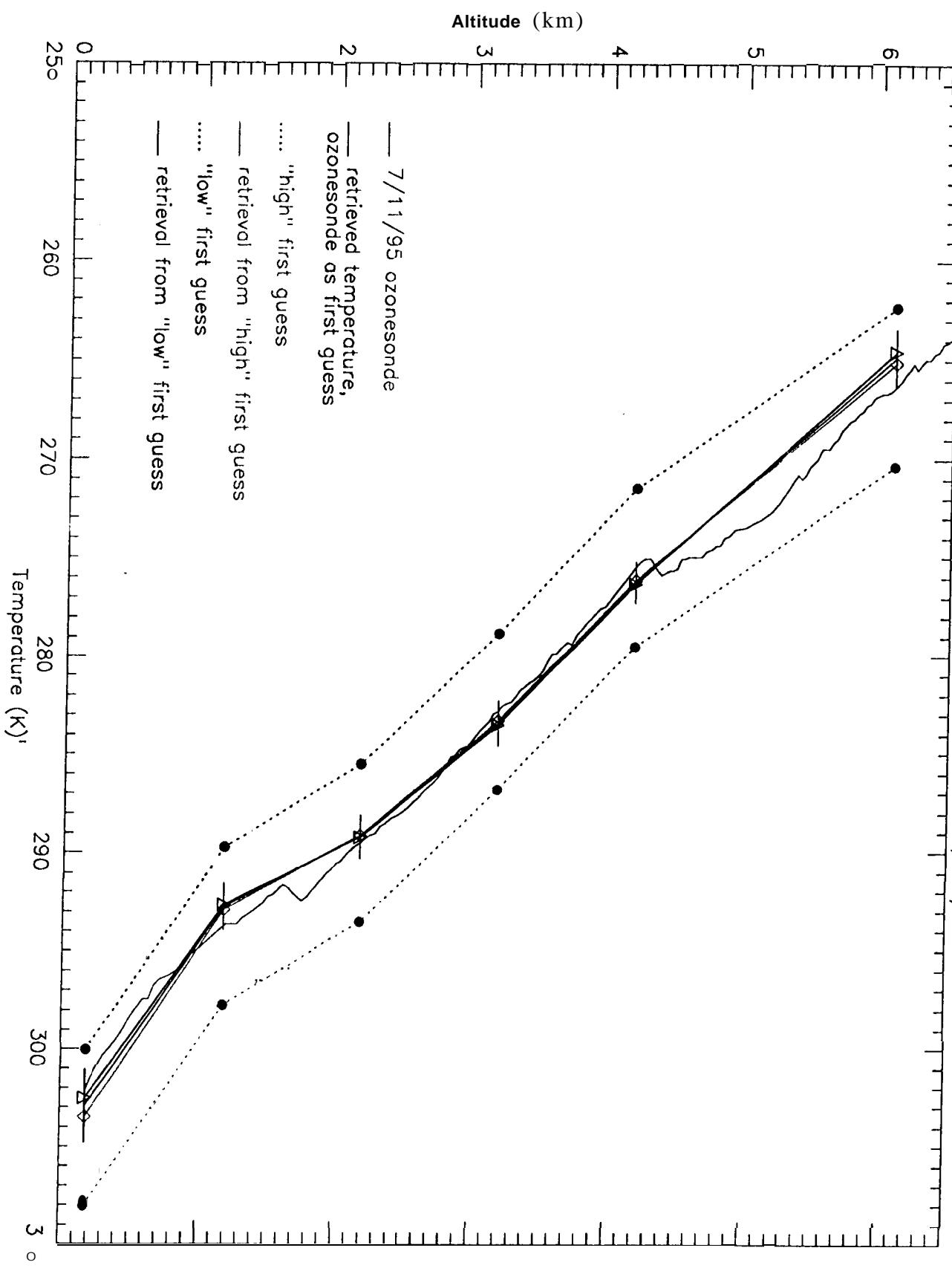
..... retrieved  
— ozone sondé

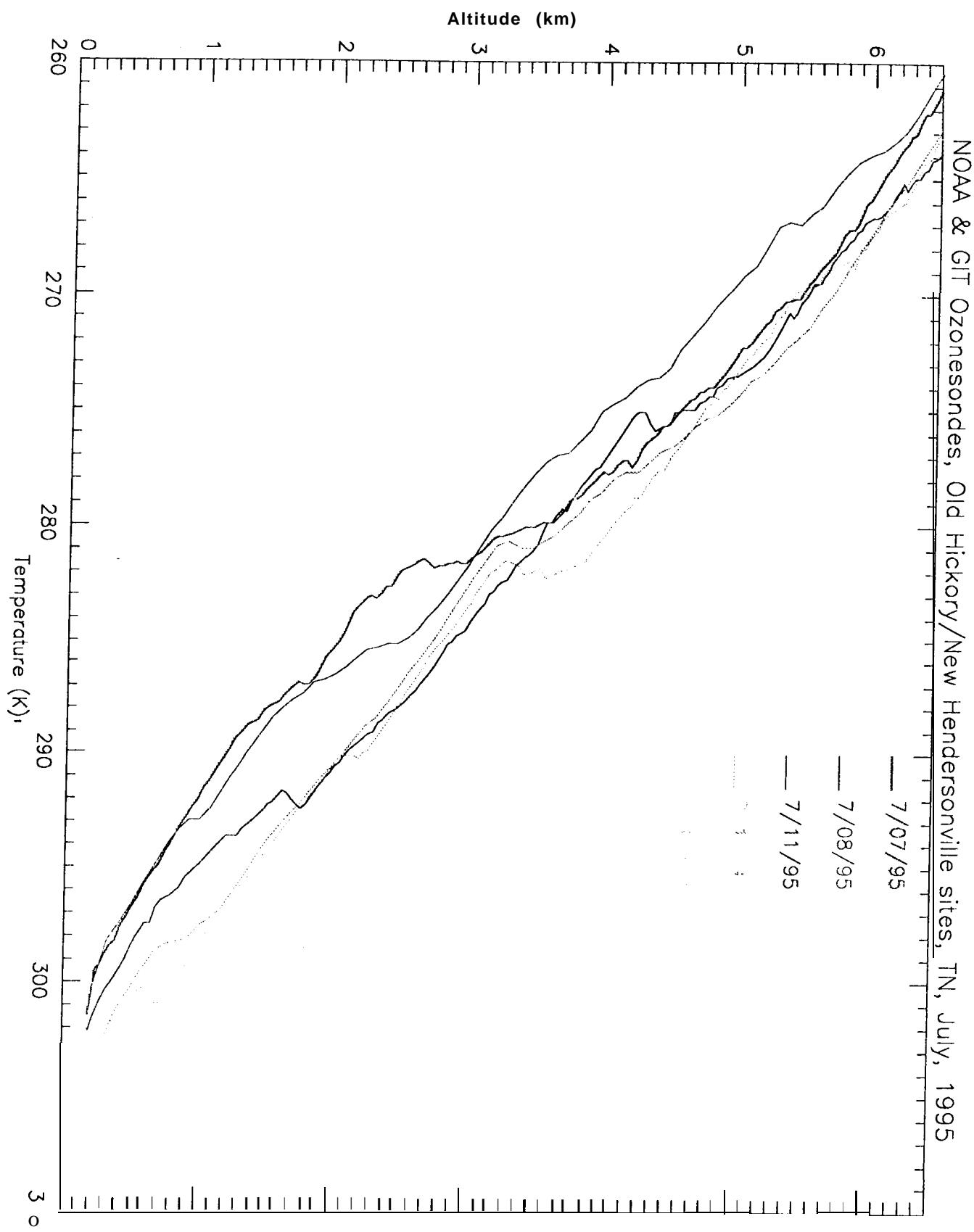


Time Series of Temperatures  
AES Results, Nashville 07/11/95



AES run 3770, scans 50–58 taken 7/11/95





# AES Retrieval Errors

## I Smoothing Error:

- Height resolutions from rows of Averaging kernel matrix:  $A = \left\{ \left[ K^T S_m^{-1} K + S_a^{-1} \right]^{-1} | K^T S_m^{-1} K \right\}$
- Also define "Fraction of Explained Variance"  $f = 1 - S_{\text{retrieved}}(jj) / S_{\text{apriori}}(jj)$  to evaluate the constraints imposed by the *a priori* covariance.

## II Measurement Errors:

Data NESR ( $S_m$ ) mapped to parameter space and propagated calibration systematic errors.

## III Model Parameter Errors:

- Error in temperature profiles from using fixed H<sub>2</sub>O vmr in temperature retrieval
- Errors in H<sub>2</sub>O, O<sub>3</sub>, CO from using fixed temperatures in species retrieval

## IV Forward Model Errors:

- Main problems are for H<sub>2</sub>O - errors in line parameters (or missing line parameters) & water vapor continuum
- Unmodelled reflected downwelling radiation and aerosol absorption/scattering

Summary of spectral measurement errors for a typical SO<sub>2</sub> observation

Filter name	Frequency range	Number of sums averaged	950-1150 cm <sup>-1</sup>	1150-1350 cm <sup>-1</sup>	1950-2200 cm <sup>-1</sup>
noise equivalent AT (NEAT) for 310 K source, at center of band	± 1.6 K	± 0.5 K	± 0.5 K	± 1.5 K	
equivalent AT for estimated 310 K, center of band	± 1.03 K	± 0.82 K	± 0.75 K	± 0.70 K	
statistical errors from radiometric calibration, 310 K, center of band					

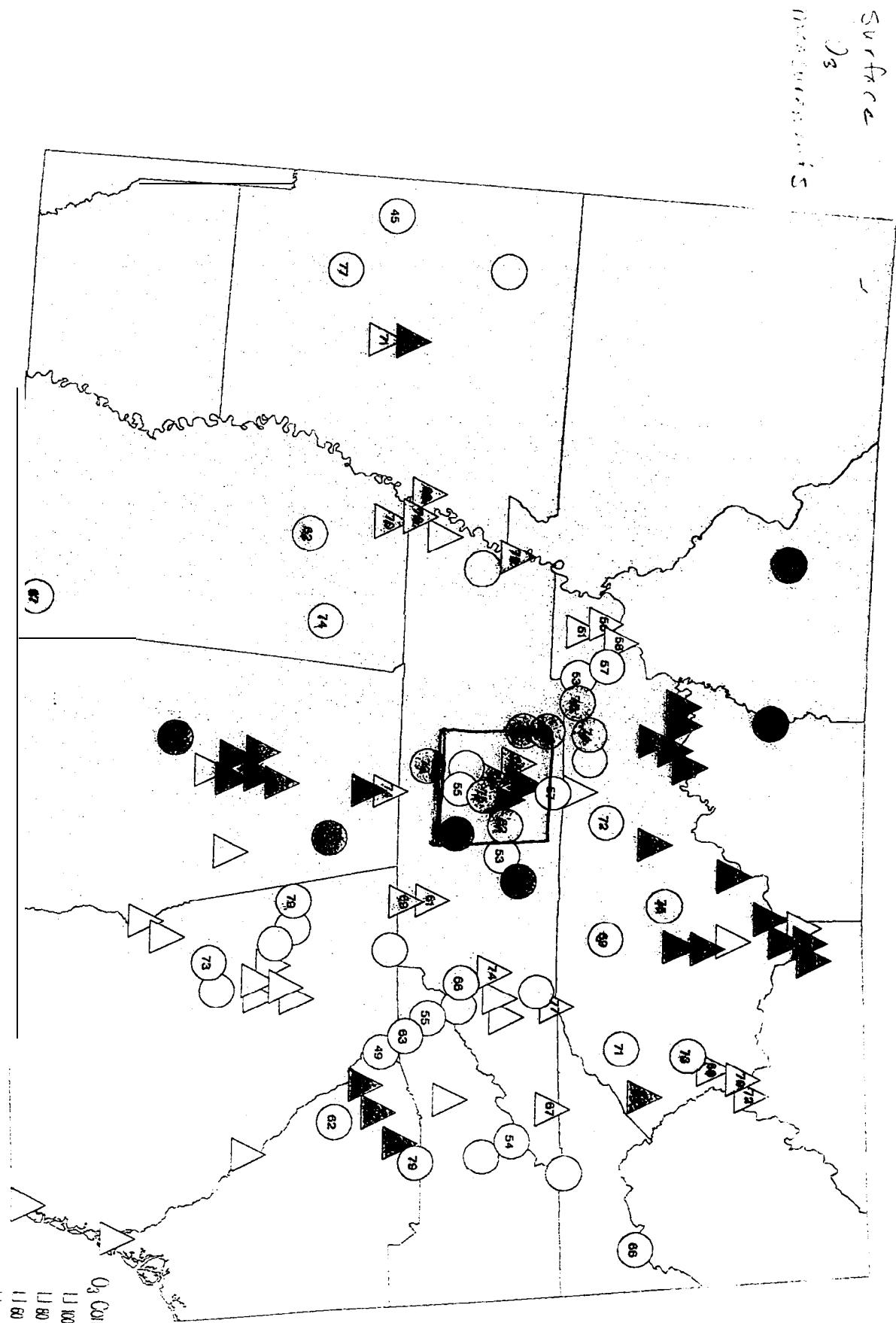
Parameter errors and smoothing information

Parameter	Measurement Error	Model Parameter Error	Statistical systematic error	Error from error from fixed H <sub>2</sub> O	Error from fixed T	Net Error	Fraction of Variance*	Vertical Resolution (FWHM) <sup>†</sup>	Q <sub>3</sub>	CO
T	±1.33 K	±1.18 K	±1.0 K		±2.0 K	0.90	2.5 km			
H <sub>2</sub> O	±0.8 %	±1.3 %		±3.8 %	±4.1 %	0.95	1.5 km			
Q <sub>3</sub>	±4.6 %	±4.2 %		±2.6 %	±6.7 %	0.97	3.5 km			
(0-2 km)	±21.3 %	±9.0 %	±0.7 %	±23.7 %	±10.0 %	0.75	0.88	0.75	±13.2 %	±11.1 %
(2-4 km)				±3.8 %	±13.8 %	0.96			±13.2 %	±11.1 %
(4-5 km)					±14.9 %				±13.2 %	±11.1 %
(0-5.9 km)						0.97				±4.7 %

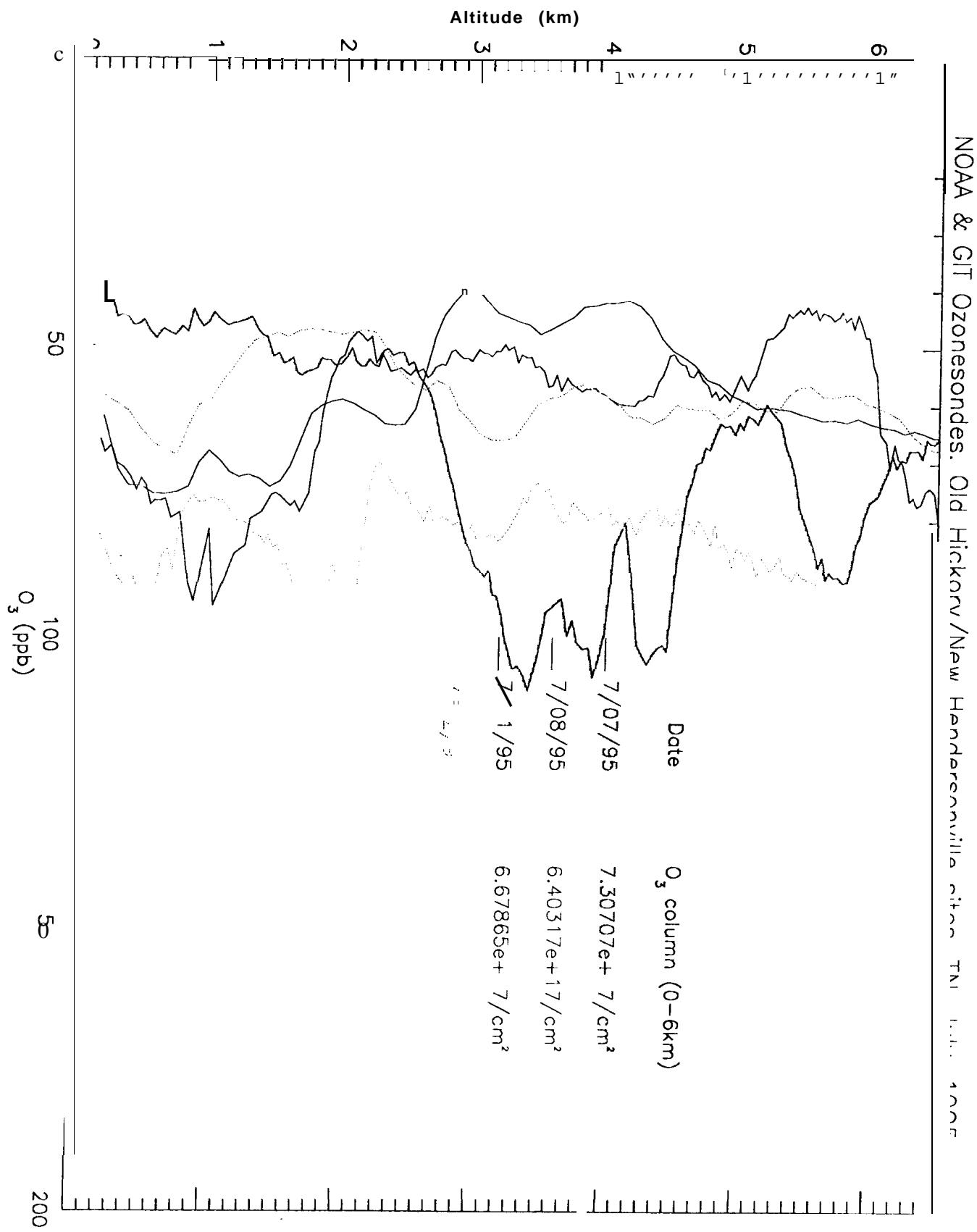
\*See text for description.

<sup>†</sup>Vertical resolution is the averaging kernel full-width at half maximum (FWHM), see text for definition of averaging kernel.

# Nashville 1995 Level 1 Network – 12:00pm July 12, 1995



Tennessee Valley Authority, Environmental Research Center, Atmospheric Sciences, Muscle Shoals, Alabama



# Correlative Measurements Comparison

- **Surface measurements:**
  - Array of monitoring stations provide 5 min. averages for T, R.H. and O<sub>3</sub>.
  - Extrapolation of T and H<sub>2</sub>O profiles to surface values from AERIS retrievals for target points near (< 2km away) station are in mostly good agreement.
- **Ozonesondes:**
  - Daily launch around 11:30 CDT. Provides T, R.H. and O<sub>3</sub> profiles.
  - AES column densities for same time of day compare well to computed ozonesonde O<sub>3</sub> and H<sub>2</sub>O column densities. AES measured O<sub>3</sub> columns tend to increase in afternoon - as expected.
  - AES measurements indicate similar trend in O<sub>3</sub> column
- **Met. data:**
  - Weather summaries and wind profiles are available - need assimilated maps
  - AES measurements are consistent with synopses of weather - dry air on 7/7, band of thunderstorms in western TN on 7/8 and stagnation conditions on 1- 3.
- **Other aircraft measurements:**
  - In progress - especially interested in NOAA P3 (in situ) and lidar results